# A gauge-invariant chiral unitary framework for kaon photo-and electroproduction on the proton

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Chiral Dynamics 2009

# Outline

Kaon photoproduction is a resonance dominated process.
Search for missing resonances predicted by quark models.

- Strong interaction at low energies:
  Chiral perturbation theory (ChPT)
- Non-perturbative methods are necessary
- These might spoil field-theoretic principles
  (such as gauge invariance)

Chiral unitary approach to kaon photoproduction

- Kaiser, Siegel, Weise (1995)
- Kaiser, Waas, Weise (1997)

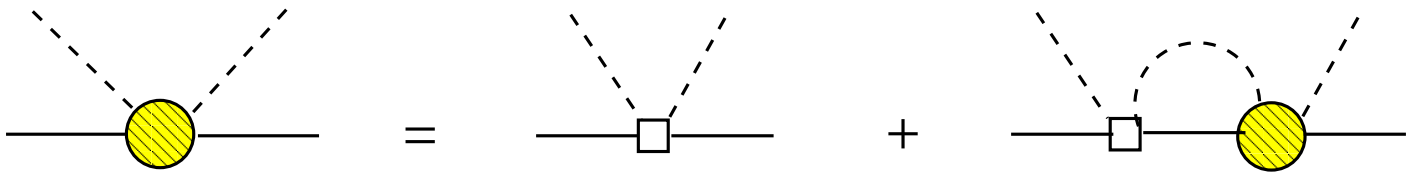
Gauge invariance and unitarity

- Gross and Riska (1987)
- Kvinikhidze and Blankleider (1999)
- Borasoy, Bruns, Meißner, Nißler (2005)

## Ingredients

- Bethe-Salpeter equation for meson-baryon scattering
- Gauge-invariant set of Feynman diagrams
- Chiral Lagrangian at lowest order
- Coupled channels:
  Ground state octet mesons and baryons

## Bethe-Salpeter equation (BSE)



Coupled meson-baryon channels:

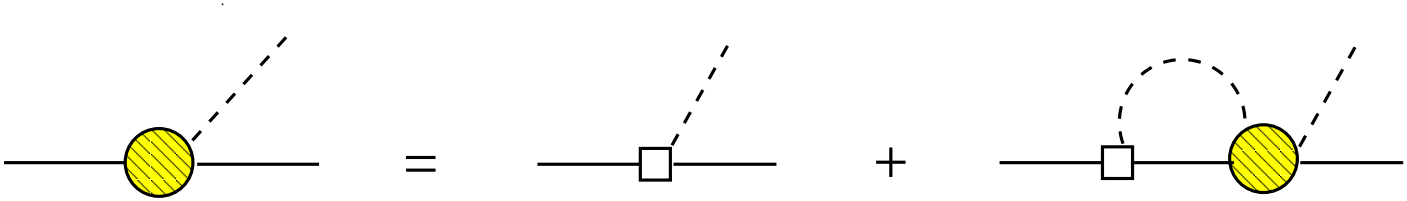
$$p\pi^0\,,\; n\pi^+\,,\; p\eta\,,\; \Lambda K^+\,,\; \Sigma^0 K^+\,,\; \Sigma^+ K^0\,.$$

Potential (Driving term) $V(q',q)$ :

$$-\frac{1}{4}f^{-1}\begin{pmatrix} 0 & \sqrt{2} & 0 & -\frac{\sqrt{3}}{2} & -\frac{1}{2} & \frac{1}{\sqrt{2}} \\ \sqrt{2} & 1 & 0 & -\sqrt{\frac{3}{2}} & \frac{1}{\sqrt{2}} & 0 \\ 0 & 0 & 0 & -\frac{3}{2} & -\frac{\sqrt{3}}{2} & -\sqrt{\frac{3}{2}} \\ -\frac{\sqrt{3}}{2} & -\sqrt{\frac{3}{2}} & -\frac{3}{2} & 0 & 0 & 0 \\ -\frac{1}{2} & \frac{1}{\sqrt{2}} & -\frac{\sqrt{3}}{2} & 0 & 0 & \sqrt{2} \\ \frac{1}{\sqrt{2}} & 0 & -\sqrt{\frac{3}{2}} & 0 & \sqrt{2} & 1 \end{pmatrix} f^{-1}(\not{q}'+\not{q})$$

$f$ : Diagonal matrix of meson decay constants.

We use the BSE to construct the extended $\bar{B}\phi B$ vertex

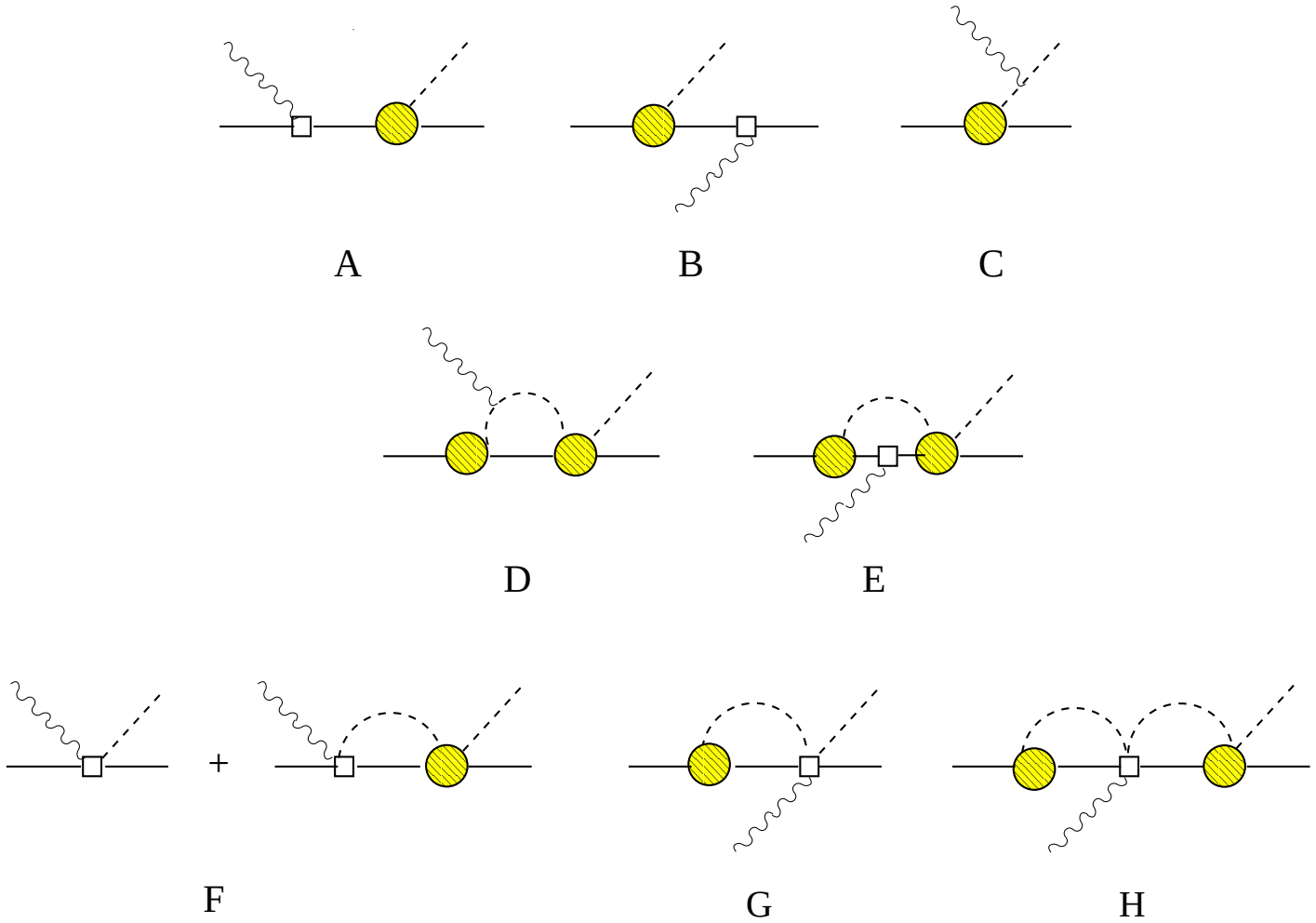


Using the meson-baryon scattering amplitude $\mathcal{T}$ as an extended vertex, we need the full off-shell dependence. In our case, $\mathcal{T}$ is of the form

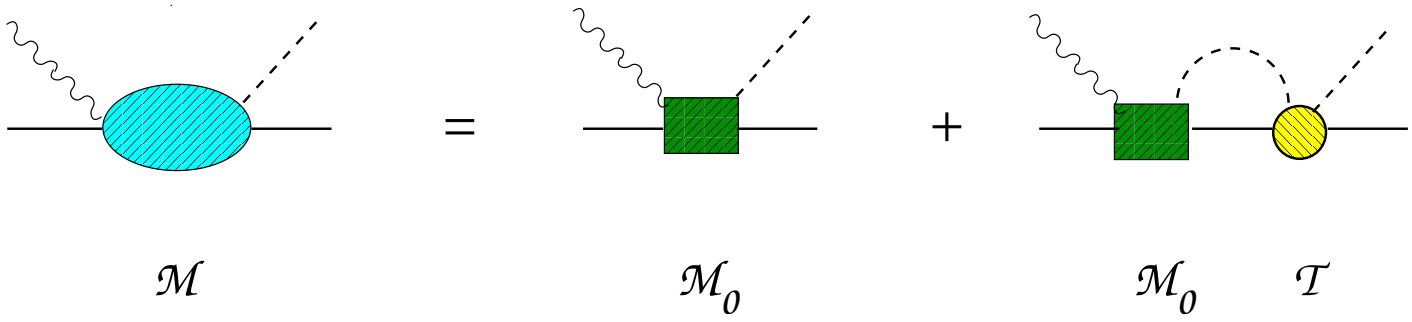
$$\begin{aligned}\mathcal{T}(q',q;p) &= \not{q}'\not{p}\not{q}T_1(p) + \not{q}'\not{q}T_2(p) + \not{p}\not{q}T_3(p) + \not{q}'\not{p}T_4(p) \\ &\quad + \not{q}T_5(p) + \not{q}'T_6(p) + \not{p}T_7(p) + T_8(p)\,.\end{aligned}$$

The coefficients $T_i(p)$ are matrices in channel space, and $p$ is the overall four-momentum ($p^2 \equiv s$).

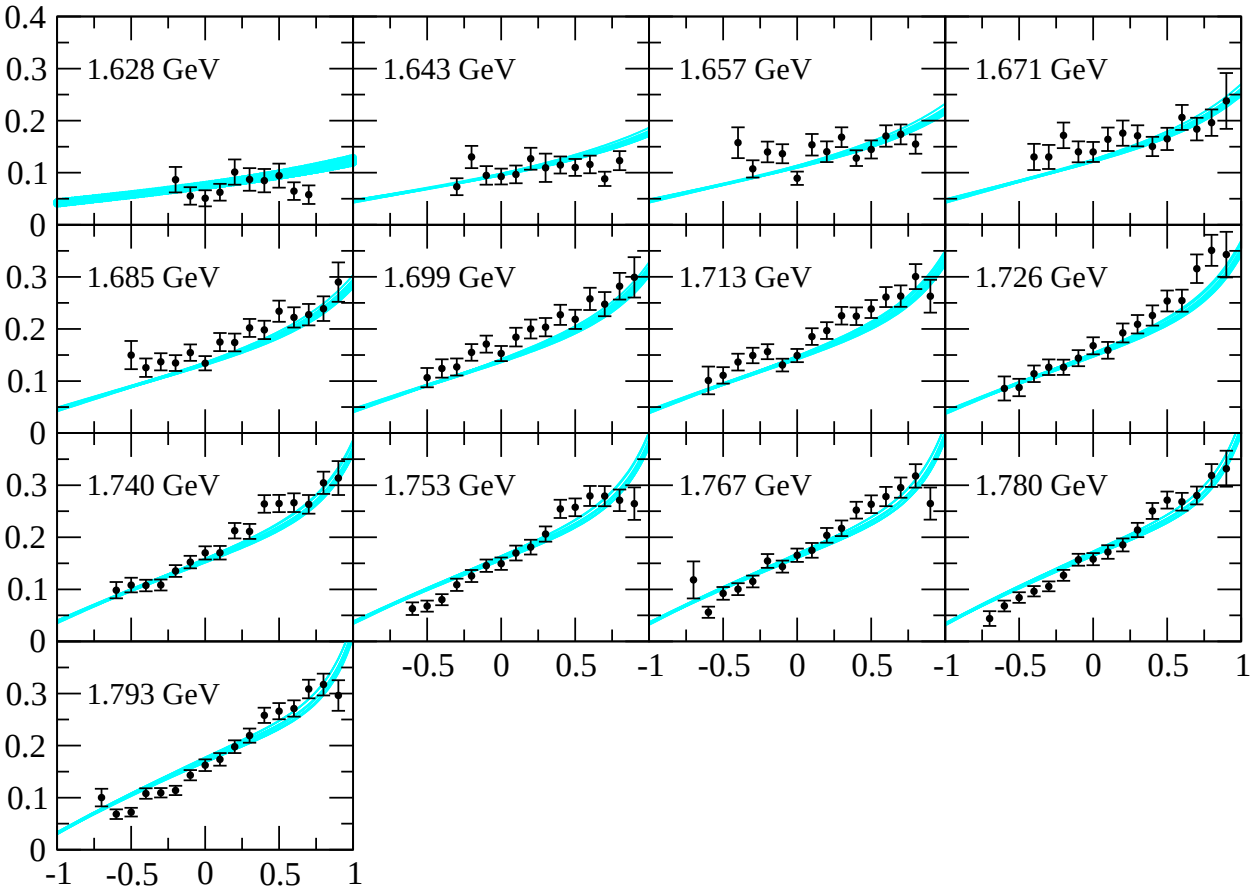
The photon is coupled at every possible position to the extended vertex:



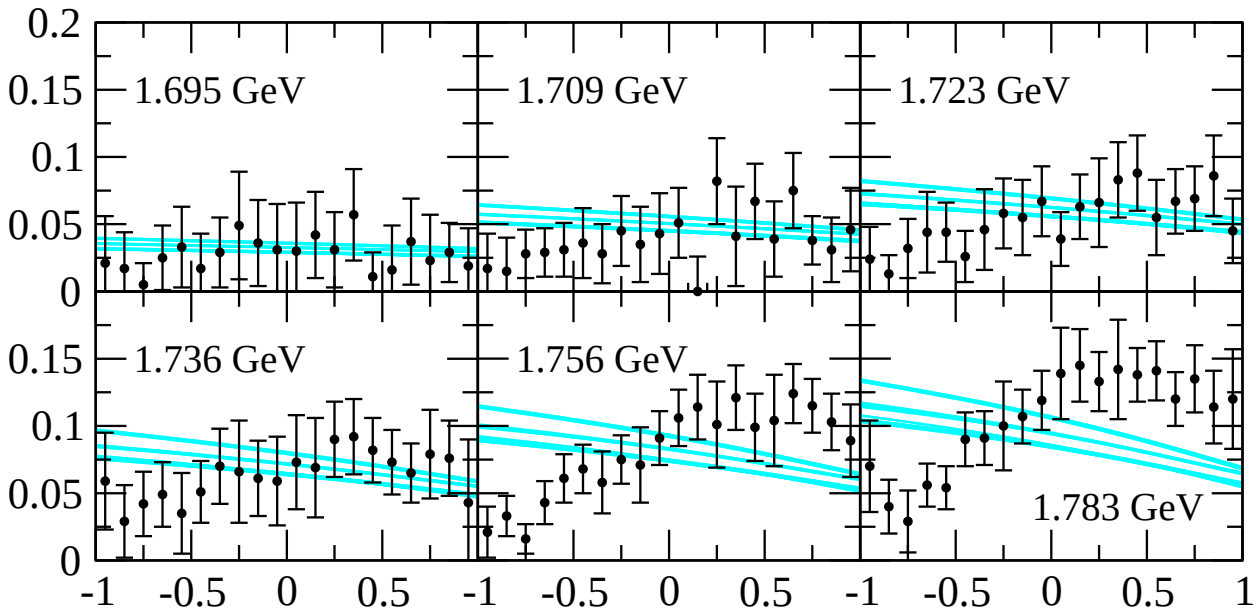
## Unitarity of the photoproduction amplitude




The final state interaction is given by the solution of the BSE.
$\mathcal{M}_0$ is real in the physical scattering region.




- Results: $\gamma p \to K^+ \Lambda$




- Results: $\gamma p \to K^+\Sigma^0$

What has been done:

- We have developed a model amplitude for kaon photoproduction which satisfies the strictures of (two-particle) unitarity and gauge invariance.
- The results for this first step are encouraging.
- The model can and will be systematically improved.

- Outlook
  - Higher order contact terms
  - Crossing symmetry (Roy-type eq.s ?)

# Reference I


B. Borasoy, P. C. Bruns, U.-G. Meißner and R. Nißler,
Eur. Phys. J. A **34** (2007)
arXiv: 0709.3181 [nucl-th]